

RESULTS OF SPACE SHUTTLE FLIGHT 41-D

HEARING BEFORE THE COMMITTEE ON SCIENCE AND TECHNOLOGY HOUSE OF REPRESENTATIVES

NINETY-EIGHTH CONGRESS

SECOND SESSION

SEPTEMBER 25, 1984

[No. 115]

Printed for the use of the
Committee on Science and Technology



U.S. GOVERNMENT PRINTING OFFICE

39-481 O

WASHINGTON : 1984

470132

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RESULTS OF SPACE SHUTTLE FLIGHT 41-D

TUESDAY, SEPTEMBER 25, 1984

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND TECHNOLOGY,
Washington, DC.

The committee met, pursuant to call, at 10:30 a.m., in room 2318, Rayburn House Office Building, Hon. Don Fuqua (chairman of the committee) presiding.

The CHAIRMAN. The committee will be in order, and, without objection, cameras and photographic equipment will be allowed during the course of the hearing.

Today the committee wants to review the results of the latest space shuttle mission and the first flight of the spaceship *Discovery*. The mission designated as STS 41-D appeared to be an outstanding success, with all the flight objectives being accomplished, including the placement of commercial payloads in their proper orbits.

This morning, with us to describe the mission results are the crew of the STS 41-D: CDR Hank Hartsfield; the pilot, Mike Coats; Mission Specialists Steve Hawley, Judy Resnik, Richard Mullane; and Payload Specialist Charlie Walker; and I want to welcome you and congratulate each of you in your part of an excellent performance.

Before—or at this time, I'd like to call on our ranking minority member, Mr. Winn, for any comments that—that he would like to make.

Mr. WINN. Thank you very much.

The CHAIRMAN. This is known as the icebuster crew.

Mr. WINN. Yes.

I'm going to do a TV show with them tomorrow morning, and I've got—I'm trying to figure out how I'm going to ask some of those questions on the problem—the last problem that you solved.

Well, I, too, want to welcome the crew again, and we congratulate you on a great job. I know it was a long wait for you, but it was certainly very, very successful in the launching of the satellites into orbit successfully. I think it sort of gave the United States, and our industry, and our contractors a boost on the back after some disappointments in some other ones.

But I, too, want to welcome the crew, and while I still have the floor, Mr. Chairman, I'll just hesitate just a minute, and you can introduce the wives of some of the crew; they're just coming in.

I want to say, I welcome the wives that I saw coming in the room, and the chairman would like to introduce you.

Thank you very much.

The CHAIRMAN. Well, I—I, too, would like to recognize the backup crew for these that are here, and I'm sure they suffered through the trauma, and delays, and disappointments right along with the primary crew, and we're happy to have three of the spouses here today; and, Fran Hartsfield, and Diane Coats, and Donna Mullane, we're very happy to have you here with us this morning. [Applause.]

The—and now I'd like to recognize Mr. Volkmer for any comments he wishes to make.

Mr. VOLKMER. Thank you, Mr. Chairman.

I'd just be very brief and say I welcome also to the crew for a very successful mission and an outstanding job after a hesitant start—let's put it that way—and just—it shows that determination will pay off, and you've shown that in the operations of the *Discovery* and all the experiments that took place, and I look forward to asking you several questions on those, especially on the one that I like to call the windowshade—the up and down telescope on the solar array—because that shows great promise for us in the future on the space station, which we're now looking at, and other applications in space for energy purposes.

So thank you very much for being here, and I want to personally, I guess I should say, also welcome our first Missourian that ever flew in space, my good friend, Charlie Walker, from McDonnell-Douglas, St. Louis; and, Charlie, good to see you here.

The CHAIRMAN. Mr. Lujan?

Mr. LUJAN. Thank you very much, Mr. Chairman.

I also want to join in welcoming the crew to the committee, and of the course the wives, but if we all might be a little provincial. Particularly, Mike and Donna Mullane are hometown Albuquerque folks in this mission.

I'm delighted to join in celebrating the maiden voyage of *Discovery*. This flight, of course, continued the long tradition of success which NASA has had, and, as we all know, success comes from hard work.

I want to thank each one of you and the other fine folks at NASA who've helped to make the space program a continuing success.

Last night I was speaking with a gentleman from industry, and one of the things that we were talking about was, in looking at the future so far as industry was concerned, and he said, "In your experience, what do you think that we ought to be doing?" He was the president of a large oil company. And of course I had no hesitation at all and said, "Well, you know, you're really overlooking something if you don't form some kind of a subsidiary or something to take advantage of the space program," and I feel that way; I think that's the future; that's the new frontier; and thank you very much, Mr. Chairman.

The CHAIRMAN. Thank you, Mr. Lujan; and, Hank, we'd be happy to hear from you and the—and the other members of the—of the crew. Welcome back again.

STATEMENT OF HENRY W. HARTSFIELD, JR., COMMANDER, SPACE SHUTTLE MISSION 41-D; CMD MICHAEL L. COATS, USN, PILOT; JUDITH A. RESNIK, MISSION SPECIALIST (MS-1); STEVEN A. HAWLEY, MISSION SPECIALIST (MS-2); LIEUTENANT COLONEL RICHARD M. MULLANE, USAF, MISSION SPECIALIST (MS-3); AND CHARLES D. WALKER, PAYLOAD SPECIALIST (MS-4)

Commander HARTSFIELD. Thank you very much.

On behalf of the crew, I guess I'd like to thank everyone for the kind remarks——

The CHAIRMAN. The mike is dead.

Commander HARTSFIELD. Oh, I have to turn it on; OK, electronic gadgetry is amazing.

On behalf of the crew, I'd like to thank the committee for the kind words we've heard here, and we certainly appreciate the opportunity to appear here and tell you about the flight.

As you might surmise, we're extremely proud of the flight. It took us a while to get it going. There are a few records there that we probably have obtained here, like the first pad abort and the most times climbing out of a spacecraft on the pad. Those kind of records we aren't too proud of, but we got some that we are very proud of, some firsts that we're proud of.

It was the first flight of a new vehicle, which, incidentally, I think as you all know, turned out to be about the cleanest vehicle yet. They seem to get better and better. The first flight of a commercial payload specialist, Charlie Walker. We had the first flight of the solar array, the largest extendable and retractable structure that had ever been deployed in space—almost 105 feet—and that worked super well. The first time we've ever deployed three satellites on one flight. The first time we've deployed a SYNCOM satellite, which, incidentally, is the first satellite that was designed specifically to be launched or deployed from a Shuttle.

So, there are a large number of things that—I'll lay in a couple more while I'm at it here. It turns out that we're the heaviest vehicle that ever lifted off of the pad down there since the Apollo Saturn days—4.52 million pounds. We also carried the heaviest payload to orbit that's ever been carried so far—47,500 pounds. So, there are a lot of things there that we're extremely proud of. We're extremely proud of the way the flight went.

I might point out that, as you know, we don't do this by ourselves. There's one great team on the ground that makes all these things go, and despite the problems we had getting ready. It does again point out the conservatism of NASA and also the expertise in solving these problems rapidly and allowing us to proceed with the launch and then have a good flight.

So, we're just the tip of the iceberg. There's a heck of a team down there supporting us, and we're proud of those folks, and I think all Americans should be proud of those folks.

What we'd like to do this morning is to, by way of a motion picture, show you a little bit of what we did in flight and tell you the story of the flight, and if it's all right with you, sir, I'd like to run the film now.

[Film shown.]

Commander COATS. Here we see the *Discovery* on the launch pad. We're walking out launch morning. As Hank said, we had the heaviest vehicle to lift off the pad since the Apollo days. It took us 2 months to get from launch minus 4 seconds to launch. So things don't always move as fast in the space business as you might think.

We had, as Hank said, over 47,500 pounds of payload, including 30,000 pounds of deployable satellites, plus another 6 or 7 pounds of ice, I guess.

Once the solid rocket boosters light off, there's no doubt that you're going someplace in a big hurry. It was a beautiful day. A lot of people think it was probably the prettiest day we've had for any of the Shuttle launches down there. So maybe waiting a couple of months was not such a bad idea.

Here's the roll maneuver right off the—as soon as we clear the tower, we start a roll maneuver. You'll see right behind the windows on the top of the orbiter there, there's a white column of smoke there. That's the—as we're going through max dynamic pressure, you can see the shock wave building up right there. We actually throttle down the main engines in two stages to hold down the effects of the shock wave. Once we got to SRB separation, we got the pyros fired and left a little film on the windows, as they do for all the Shuttle launches.

Mr. HAWLEY. Mr. Chairman, as you're aware, we had a very ambitious flight plan, and, to the extent that you can in zero-G, we hit the ground running with a satellite deployment on the first day.

My responsibilities required that I sit up front, and with the window shades in, of course, I didn't get to see anything; so, I'm real glad we got some good movies to show you, because that gives me an opportunity to see the satellite deployments.

The technique involved in deploying these satellites is slightly different from on previous satellite deployments because of some modifications that have been made to the software and hardware that's associated with the deployment of the satellite, and that all worked extremely well. And, we have a system that is even better than the one that we have flown on previous missions.

The Satellite Business Systems satellite was the payload for flight day one, and the shuttle is responsible for providing the pointing and providing the stability. The orbiter's computers provide the pointing accuracy; and, as you see, we spin the satellite up prior to deployment in order to give it spin stabilization.

In the next sequence, you'll actually see the deployment as it occurred. And, if you look very closely, you can see the film move a bit. The deployment firing up the pyrotechnics that severs the hold-down clamp on the PAM vehicle causes the vehicle to shudder, and it's quite a bang, which we all heard. Then you can see a little bit of vibration there as that takes place.

The satellite is very stable, as you can see. Notice how it tracks straight up the vertical tail, and we were able to follow it with the cameras quite a distance after the deployment. And, of course, the PAM vehicle worked exactly as it was supposed to, and the apogee kick motor on the SBS satellite worked exactly as it was supposed to, and the SBS is on station.

Colonel MULLANE. On flight day two, we went two for two by deploying the SYNCON satellite.

As Henry mentioned, the SYCON is the first satellite that's been designed strictly for deployment from the Orbiter. In the case of the PAM's, those, as you well know, can be deployed on expendables or on the Shuttle. So, that's why it has such a large diameter. It weighs about 15,000 pounds, which is twice the weight of the PAM's, and as you can see, it's—gets its initial spin stabilization from being deployed from the payload bay. It's a spin stabilized satellite, just as is the PAM. It just uses its thruster rockets after it's deployed to spin up to a stabilized RPM.

The Omni antenna on the top is elevated about 2 minutes after deployment and is used for ground communication. The helix antennas that are stowed there are used for the payload package which is a UHF communication package that's used by the U.S. Navy.

And speaking of the U.S. Navy, here comes Mike Coats floating up to the upper deck.

Commander COATS. After each of the satellite deployments, we did a short burn to give ourselves a little more separation from the satellite motor before the satellite's motor fired, which is 45 minutes after we deploy the satellite. You'll see the Orbiter's engines fire here. The initial flash is visible right here, and then you don't see anything in the vacuum of space while the engines are burning. You'll see the tail-off in just a few seconds. Right there's the tail-off. The burn stopped, and there's a little flash of a thruster right there.

Mr. HAWLEY. One of the requirements that was a part of our mission was a large amount of photo documentation, and this is a sequence of Hank trying to set up the IMAX camera in the overhead window to film some of the activities. And, the reports are that the IMAX film that we took on the flight was very, very successful. We haven't had an opportunity to see it yet, but we were excited by that news.

On flight day three, we became the first Shuttle crew to ever deploy three satellites with the successful deployment of the Telstar satellite for AT&T. And, once again the system was completely normal and the satellite worked on-board and post deployment exactly as we had hoped.

We had a requirement to document all of the perigee kick motor burns for all three satellites. Obviously there was some engineering interest in how they performed, and the next sequence will show you the on-board footage of the burn of the AT&T satellite.

We were fortunate enough to manage to record some lightning on the ground at the same time; and, there's the ignition of the perigee kick motor on the PAM vehicle that was boosting the Telstar satellite into its transfer orbit. All three motors, of course, burned exactly as they were supposed to, and we were able to track it. Judy, using the arm and the camera on the wrist of the arm, managed to film this, and you can see it tracking off into its transfer orbit with the Earth's horizon. And, in the upper right-hand portion of the frame the constellation of Orion, which we got to see and record. And, of course, AT&T is in its proper location on orbit at this time.

Mr. CHARLES WALKER. Also on this flight, the McDonnell-Douglas Corp. Electrophoresis Operations in Space payload that I conduct-

ed. Here I'm working at the electronics control module preparing to command and control operate the separation of some pharmaceutical materials using the weightlessness of space to improve the mass quantity throughput and purification of that material.

Some of the routine operations were calibrations of the equipment; also, sampling of the separated substances, which I'm doing here. We had on board a specific assay kit, a wet chemistry type kit, to determine that the material was in fact present. And, we did successfully separate materials and have had a successful return of that quantity of substance.

Ms. RESNIK. On flight days three, four, and five, we extended the solar array wing. This was—as Henry mentioned—the largest structure we have ever extended in space. It extended over 105 feet, yet it was also so lightweight and flexible that it only weighed 300 pounds.

The capability of this solar array is about the equivalent of almost as much power as we use on orbit with the Orbiter. In this case, we only had a few panels that had active solar cells on it, and we did get some performance characteristics of that. The array unfolded just like an accordion, as you would expect, very well behaved, and we got some good photographs of it.

It was fairly translucent. And we were in a tail/Sun attitude often, so we got to see the Sun shining through the array.

This structure has capability in the future not only for a Space Station type operation but also for other type of platforms in that it's very lightweight, very easy to extend and retract, very well behaved.

Here we are coming across Baja, you can see in the background.

During the flight, we tested the dynamics of the structure to see how stable it was by firing a preset condition of Orbiter vernier pulses to see if the thing was very stable, which it was. It was very well behaved. We had very little oscillation of the mast, and we were able to maneuver the Orbiter to different attitudes with the mast extended.

I think it turned out to be a lot more less flexible than expected, which was a good sign. And, we hope to see uses of structures similar to this on both the station and perhaps for use to supplement power on the Orbiter.

We took a lot of photography of this structure, and here you see—as we're coming up on a sunset, you can see the shadow of the tail through the array.

Commander COATS. For the first flight of a new vehicle, we had remarkably few equipment malfunctions.

One of the few problems we had was a display unit. A cathode ray tube—we call it a CRT—up forward failed a couple of hours after we got on orbit. It really wasn't important to us right then, but as soon as the satellites had been deployed and the solar array work was done, we decided to swap it out with the aft unit. So we did what we call an in-flight maintenance here to swap out the two units.

There's some advantages and disadvantages to repairing and working with tools on orbit. One of the advantages is, you can get up in the nooks and crannies very easily, floating in zero G. One of the disadvantages is that, even though you outweigh the screwdriv-

er by about 185 pounds, you still have to anchor yourself down, or you're going to lose the battle here.

We did successfully swap out the display units and had three good display units for entry and landing.

Commander HARTSFIELD. Later in the flight, we had the problem with the dump nozzle in which the large icicle formed, and it became our task to go look and see what it looked like. And, then the ground did a super job of coming up with a plan to knock that ice off using the arm. Here's what it looked like; and, as you watch that bottom port, you can see ice form before your eyes as we tried the waste water dump. And, it was amazing how fast that icicle formed on the bottom. In a matter of about 10 seconds, we threw out this great hunk of ice there. We stopped the dump at that time and then decided we needed to look at some other plans or find some way to get rid of this ice.

As I said, the ground did a super job of coming up with the plan to use the arm to do this, and it worked extremely well. During this operation, Judy handled the communications to the ground and kept me honest on working with the arm; deployed the arm, and moved it into a position to observe the ice.

We had spent 2 days Sun side prior to this attempt, and, as you see here, the size of the icicle has reduced considerably, but we still needed to knock it off.

Here you see the ice as the arm moves in. Now, the at the point I hit the ice with the arm, I couldn't see it, because the camera's on top. If you'll look closely here, you'll see a little chip of ice float off out to the—right side of the screen, and that's the moment of impact. There it goes. We were certainly relieved when we backed the arm up and took a look, and, sure enough, the big icicle was gone.

As we zoom back here, you see the black spot there, just above the top of the arm, and that's the port with the large icicle gone from it, and here's what it looked like out the window right after we broke it off. Mike Mullane saw it go out the window and grabbed the camera and took a picture of it; a pretty good hunk of ice.

Colonel MULLANE. We had a short game of handball with the little rubber penguin we had on board. It demonstrates some of the effects of weightlessness.

This was a more scientific demonstration here. We were trying to show the physics of a frisbee deploy.

When the SYNCOM is deployed, all it gets is a push by a spring, a tangential push on one side, and yet the payload with that one push will rotate and translate. You get pure rotation and translation, and that's exactly what we saw when we deployed the SYNCOM. And, we were just attempting to demonstrate that on the mid-deck here with that circular filter, and fortunately the physics looked just as we had seen them. It would have bothered us, I guess, if we hadn't seen the same thing.

People are always curious what our meal preparations are like, so we filmed the preparation of some strawberries. You can see that we have little plastic cups that require rehydration.

We have—the fuel cells on board generate a surplus of water, so we have plenty of water. So, most of the food we carry is dehydrat-

ed. So we put it in that water dispenser, select the number of ounces of water we want, and dispense it into it, and then are able to rehydrate it by massaging it with our hands, with our fingers. And after you get it good and rehydrated, you can take a pair of scissors or a knife, cut open the top, and eat from it. And, if you're real careful, you won't get a lot of food drifting out of the plastic. Some types of food are a lot easier to eat this way than others. Rice is pretty difficult to eat.

Here's mealtime in the mid-deck. You can see that we have those trays, and we're able to anchor the food packages on them, and eating in zero-G is one of those things that there's a lot of overhead associated doing something like that. It's not as easy as just going to your refrigerator, and opening the door, and grabbing something, and throwing it in the microwave. It takes a lot more time than that.

Now we had a—there's Henry looking for dinner.

Somebody—I think Steve Hawley once said it gives a new meaning to "pass the potatoes."

Ms. RESNIK. As we do on Earth every day, we tried to get on to the treadmill to do a little bit of exercise. And, we can all attest that it feels just as good to stop in zero-G as it does in one-G. And, this is what the mid-deck looked like with five people sleeping.

The natural position of your hands in zero-G, if you relax your whole body, is for them to float up like you see here. It looks a little bit like a morgue, but it was really very comfortable.

Commander HARTSFIELD. Sunsets in space are always beautiful, and I think everyone—every time a crew comes back, they try to bring back a picture of a sunset. The colors are very vivid. You can always see the thunderheads, as you see in the center there, on the horizon, right above the rim of the Earth. One of these days, we're really going to capture it properly.

Entry: The orbit burn was nominal. Here we see the Orbiter picked up by the tracking cameras at Edwards. Those trails are coming from the RCS jets.

We had program test inputs put in by the computer throughout the flight that—we had 11 sets of inputs—that caused the control surfaces to move in a program manner such that we could refine the aerodynamic characteristics of the Orbiter.

The Orbiter flew really well. It flew very much like the training airplane. I can't say enough for the training airplane, of how much it did to make me feel comfortable in bringing this big bird in for the first time. Here I'm rolling out on final, picking up speed to about 285 knots and 19 degree glide slope.

The Orbiter actually feels a little more solid to the pilot than the training airplane, but that's the way you want it.

Mike put my gear down for me here. The gear went down at about 300 feet above the ground, and we were doing about 270 at the time.

As I said, from here on in, it was in the groove just like it had trained to do, and it worked out real well; touched down at 195 knots, which was the target touchdown speed; 185, started the nose down. It looks rather gentle here, but in the cockpit we thought the wheels were coming through the cabin.

We rolled to a stop on the lakebed and went through a normal shutdown procedure, which takes about 35 minutes, and came out to greet our boss, George Abbey, and then take a look around the bird. It turned out to be a very clean bird. We didn't see that much wrong with it; it looked almost as good as when we took it away from the Cape.

Discovery is a mighty fine airplane.

[Applause at end of film.]

Commander HARTSFIELD. Mr. Chairman, that, in essence, is what we did on the flight, to give you a quick overview.

We'd like to say once again that this cannot be achieved by just a few people; there's a lot of people responsible for all this happening. The key, as it always has been, to great successes is people, and the people that work at JSC and the remarkable people that helped build this airplane, the people that helped support it while it was in flight and prior to flight, all these people play together as a great team. They're highly motivated, and we're—I think I speak for all the crew—are extremely proud to be a small part of that team. We seem to be in the limelight, but these people really belong in the limelight as well. They're a great team, and we're real proud of them.

The CHAIRMAN. Thank you very much. We're all very, very proud.

Do you have any slides or—

Commander HARTSFIELD. We have no slides for you this morning, sir.

The CHAIRMAN. Oh, OK.

Commander HARTSFIELD. One last act I do have. I do have a couple of things here that I'd like to present. We have for you, Mr. Chairman, a small memento of the flight, which is a flown American flag and a patch from our flight as a way of appreciation to your long support for our program and the work of the committee to make all this possible. You, too, are part of the team that supports us and makes it all go.

And also we'd like to present the ranking minority member, Mr. Larry Winn, a memento. I understand he's leaving us after this term. We're going to miss him, and we want—as our way of saying thanks to you for all the support you've given us over the years.

The CHAIRMAN. Thank you very much.

Mr. Winn?

Mr. WINN. Thank you, Hank.

I noticed that there was a Kansas flag on line, and I remember Mr. Volkmmer said that he wanted to pay tribute to the first Missouri astronaut, Charlie Walker, and I join him in that, but I'd like to point out that Kansas has had three, and if we count—all three—Joe Engel, Ron Evans, and now Steve Hawley, and then we've adopted Sally Ride since she's married to Steve Hawley. So we count four.

On the troublesome flowpipe—and that's given several of the other STS's some problems before, if I remember correctly, on the freezing—why couldn't the ground and the engineers design some sort of a vibration—just turn it on and let it vibrate every so often so that it wouldn't freeze, or would that work, do you think?

Commander HARTSFIELD. Well, I'm not exactly sure how that would work. I know that we are studying the problem. In fact, I think we may have a key already to what might be causing that problem. There seems to be a strong relationship between the dump pressure itself and the formation of the ice. So, it may be as simple a solution as increasing the dump pressure. They're still looking at that.

They're also looking at the possibility of modifying the area around that nozzle, like going back to tile rather than the blankets, as you saw here—putting a little small tiled area around the nozzle so that the ice wouldn't have as great a tendency to stick to the side of the Orbiter. I know that we're working as hard as we can to come up with a solution to that, and we'd be happy to try to get that data to you.

[The information follows:]

Our primary focus is on taking the necessary steps to preclude nozzle freezing, thereby obviating the need for mechanical devices such as vibrators or inflatable surfaces to prevent ice buildup.

In-flight procedures have been modified to cease dumping water when the nozzle temperatures declines to a specified value (50°F for waste water). The nozzles are also preheated to a higher value (25°F vs 200°) before water dumps. To help maintain nozzle exit pressure, Tank A will be dumped directly rather than through Tank B. Maintaining a sufficiently high nozzle exit pressure is believed to be a key factor in the prevention of ice formation.

All vehicles are now equipped with two hydrogen gas/water separators in lieu of one. This increases the water dump nozzle exit pressure.

Thermal-vacuum chamber tests will be conducted in the near future to determine the minimum allowable nozzle exit temperature and pressure as well as the optimum nozzle exit configuration. The exit nozzles will be tested with surrounding tile and AFRSI to determine the effect of surface roughness on ice adhesion. The results of these tests will be factored into the flight procedures and nozzle exit configuration, as required.

Mr. WINN. What were you afraid of? If the ice broke off, what were you afraid of—that it would hit the tail?

Commander HARTSFIELD. I think the concern was that if the ice remained there and then broke off in entry, that it could hit the OMS pod, and there was a lot of discussion and a lot of controversy, really, over—as I understand it—how much damage that would do—

Mr. WINN. Could do.

Commander HARTSFIELD. Could do—yes, sir.

Mr. WINN. Hm-mm.

Now, if you worked the arm—is that right—or did Judy, or you were both involved?

Commander HARTSFIELD. I worked the arm, and Judy looked over my shoulder; yes, sir.

Mr. WINN. OK. Now, if the arm—if you had not been successful—and you said you were very pleased with it—if the arm had hit that pipe hard enough to break the pipe off, is that possible? Does the pipe stick out?

Commander HARTSFIELD. No, sir. It's flush-mounted.

Mr. WINN. Oh, it's flush; all right.

Commander HARTSFIELD. It's just the port—

Mr. WINN. OK. So all that you could hit would either be the side of the Orbiter with the arm, or you can hit the ice?

Commander HARTSFIELD. Yes, sir, and the information that we had at the time that we could hit the side of the Orbiter, because it'd be a grazing blow without doing any great damage.

Mr. WINN. Hm-mm.

Commander HARTSFIELD. Our biggest concern was hitting the wing, which was about a foot under the arm.

Mr. WINN. Hm-mm.

Commander HARTSFIELD. And had we hit the wing, which is—as the carbon leading edge, we could've done some bad damage there, but the—the arm performed extremely well, as well as it has almost on every flight.

Mr. WINN. Did you do that manually?

Commander HARTSFIELD. Yes, sir.

Mr. WINN. Computers were not involved in that in any way whatsoever?

Commander HARTSFIELD. Well, they are in the sense that we make manual inputs to the system, and the computer resolves the problem as to which joint to drive on the arm to make it go in the direction that we command it to go.

When I say "manual," that means that rather than putting in a computer program that did it automatically, it was manually controlled.

Mr. WINN. Did you have any other problems—real problems that you think that the committee should be concerned about as far as future Orbiter flights—shuttle flights?

Commander HARTSFIELD. None come to mind at the moment. I think, all in all, *Discovery* was a very clean vehicle. We had very few problems to contend with of a major nature. In fact, the dump problem was probably the worst thing that happened to us in flight, and I view that as a minor thing that could either be solved by a small design change or procedural change.

The other systems performed admirably well. And, I think the success of our mission, the fact that we were able to accomplish 100 percent of what we set out to do despite having to alter our time line, our attitude profile, to spend 2 days Sun side, take time out to go look at the ice and knock it off—I think the success of the mission can be attributed in large part in the fact that the Orbiter performed so well.

When the Orbiter works well, you're able to work.

Mr. WINN. Thank you, and congratulations again.

Steve, I would just like for the record to show you told me how far that the Kansas flag has flown in space. How many miles in it? I think the audience would enjoy that.

Mr. HAWLEY. I think we worked that out to be approximately 2.2 million nautical miles on that Kansas flag.

Mr. WINN. Well, as the song says, that shows that everything's up to date in Kansas. [Laughter.]

Thank you, Mr. Chairman.

The CHAIRMAN. Thank you, Mr. Winn.

Mr. Brown?

Mr. BROWN. Tell me a little something about the solar panel. I'd like to know both what its characteristics are in terms of size and power output and so forth, but what—what are its potentials? Can those be mounted in arrays? Can they—could we have a series of

them providing power? What—what can we expect in terms of utilizing that as a source of space power in the future?

Ms. RESNIK. The particular solar array that we flew has the capability of 12½ kilowatts of power, which is the equivalent of one of the modified Orbiter fuel cells. It is 300 pounds in weight, yet it is 105 feet long and 13 feet wide. So it's quite a large area for a very small penalty of weight. It is a very flexible structure. It's the first large flexible structure we have ever deployed from the Orbiter or on any large vehicle or platform. It does have the capability of retracting quite handily in case you would, for example, use it on a Station and need to retract it for a vehicle to come mate with the station.

So, it only takes a few minutes to extend and retract it. It is very well behaved. It has a lot of capability as far as power consumption is concerned for a small penalty.

You could conceivably, if the design is so manifested, fly several of these types of arrays on a Station, for example, or on a manned station or on a platform of some sort that you might go back to visit, and in the daylight side, it can generate quite a bit of electricity for only a few hundred pounds of payload weight.

Mr. BROWN. Do you have associated storage batteries with it or something that—that could store the energy?

Ms. RESNIK. Should we use something like this in the future on a Station, I think that there is some design engineering that has to go into storage on the dark side. Right now, the capability that we tested was just the basic technology of extending and retracting and the performance of the cells.

Mr. BROWN. Yes. Thank you very much.

The CHAIRMAN. Thank you, Mr. Brown.

Mr. Lujan?

Mr. LUJAN. Thank you very much, Mr. Chairman.

Everything seemed to go so well. I guess maybe the only real disappointment that we went down for the first one and you all didn't take off, but other than that, why, everything seemed to go well.

I just have—have one question, and I may be—everything went so well that perhaps I move on to the next step, figuring that you have everything under control in the whole astronaut training, moving into training for the space station and, whether it's manned, or a platform, or whatever it may be. Has that begun in the astronaut training, or has it been always?

Commander HARTSFIELD. We have several people in our office that are working closely with the team at JCS that's developing the proposals and looking at designs for the Space Station. We're, as of now, not training specifically for the Space Station.

Mr. LUJAN. Not anything to live there or do any work there except for Charlie and, with the electrophoresis I guess that's really related to the space station.

I just wondered if we were that far into it that the training might—

Commander HARTSFIELD. Oh, we're very much interested in the Space Station. And we're supporting it from our office as much as possible, because we think that we need to get our inputs into the program now as it evolves, to optimize the crew-machine interface.

Mr. LUJAN. Yes.

Thank you, Mr. Chairman.

The CHAIRMAN. Thank you.

Mr. Bateman?

Mr. BATEMAN. Thank you, Mr. Chairman.

I'd certainly like to congratulate the crew of the maiden voyage of the *Discovery* and to simply say to them and to all of the NASA team, of which they're only the most visible part, that we're very pleased that there's so much of the right stuff in NASA that makes these things possible that you've done. We're very proud of you.

The CHAIRMAN. Thank you.

Mr. Nelson?

Mr. NELSON. Thank you, Mr. Chairman.

When the engines had to shut down, we got a lot of commentary about how tragic it was and so forth, but some of us on the committee were trying to remind the public that it was working exactly like it should, that the computers shut them down when you had a problem.

What was your reaction to that, Mr. Hartsfield?

Commander HARTSFIELD. Well, it was just as you've stated. I guess—and I speak for myself and I think for all of the crew really—that we had no great concern at the time it occurred.

In fact, my most immediate reaction was one of bitter disappointment, because we had just scrubbed the day before, and here we were trying again, and we got the engines lit, and I thought at that point, "Well, we're on our way."

In fact, my crew gave me a hard time because shortly before that, I made some statement. We went through 31 seconds, and I said, "Well, we're on our way, unless something bad happens," and it did.

But the system is designed to take—this is the on-board computer system—to take a quick look at all the critical parameters, and if there's something not right, to stop the launch sequence. And, when it saw the problem with the fuel valve on the number one engine, it did exactly that; it stopped the launch sequence and issued the shutdown commands. And, we got the red lights in the cockpit and then felt, of course, the engines shut down, and at that point I knew we were not going, and I had no concern because I knew that the redundant set launch sequencer had done exactly what it was supposed to; the countdown clock had stopped; and I think our overriding reaction was just disappointment that we were not going anywhere.

Mr. HAWLEY. Mr. Nelson, if I could—

Mr. NELSON. Please.

Mr. HAWLEY. Just for the benefit and the information of the committee, I, because of the nature of my assignments within NASA before the flight, have had an opportunity to be involved in more than a dozen countdowns, and I'm quite familiar with the procedures and all that takes place. And, I'd like to say that I think we had a good system in place at that time, and the situation was handled professionally. And what has resulted from that experience, I think, is an even better system.

The software that supports the countdown in the firing room—what's called their ground launch sequencer—has been modified since the June attempt and is significantly better at providing the

operators with the information they need should a contingency like that arise. We've added safeguards at the pad to more rapidly assess whatever fire danger might be present for the people in the firing room to make decisions regarding crew escape. We've done some bookkeeping things with regards to the procedures that are in place and that everyone was referring to at that time, to make it easier for the controllers in a time critical situation to have the procedures in front of them that they need.

So, I think that, if anything, we've come out of this experience far better configured to handle an occurrence should it happen again in the future.

Mr. NELSON. Well, thank you for making that point.

Let me ask you. Hank, you were talking about the training for the landing. You were talking about your training in the G2?

Commander HARTSFIELD. Yes, sir.

Mr. NELSON. How about your—your training in the simulator? Does it give you what you need—the simulator back in Johnson?

Commander HARTSFIELD. Oh, the simulator is a powerful tool for training the crew for flight, and I guess you have to, of course, realize what the limitations of the simulator are. It does an extremely good job for what it's capable of doing. Now, I think all the crew will attest to the fact that what we experienced on ascent and what we experienced on orbit—there were no surprises, because the simulator had shown us all of that. The task of landing a vehicle is a different story though. No simulator can give you the feeling and the real world contact of landing a vehicle like that.

Remember, the pilot's eyes are 33 feet above the ground when you're landing. You're talking of a height above the ground similar to a 747. Your depth perception judgment is not that good. You don't get any of that depth perception in the simulator, because it's really two-dimensional scenes you're looking at.

The whole task can only be done in a flight environment, because no matter how good a simulator it is, you still know it's a simulator.

Mr. NELSON. Now, I've seen the configuration when John Young was landing the G2 in practice, and he had someone that was going with him sitting in the right seat.

Now, do you flip it when—Mr. Coats, would you—you would practice in the right seat, and whoever was with you would sit in the left seat?

Commander COATS. No. The way we use the G2 is, one pilot goes up—one astronaut. Either Hank would go up on a flight, or I would go up on a flight.

The instructor pilot sits in the right seat and is responsible for the G2 and all the systems in the G2. The astronaut flies the Orbiter half of the vehicle, if you will, that takes over at about 35,000 feet and can fly it on down to simulator touchdown, eye height.

So there's just usually one astronaut on board, training for a whole 2-hour session, and the man on the right is simply the instructor pilot, and he can simulate different situations, different malfunctions, for the astronaut.

Mr. NELSON. Thank you, Mr. Chairman.

The CHAIRMAN. Thank you.

Mr. Boehlert?

Mr. BOEHLERT. Thank you.

You've lived through the longest four seconds, I think, in recorded history. How, over a 2-month period, do you maintain a constant high and state of readiness? I would just think you would be challenged to the ninth degree to sort of be on a downer. How do you do it?

Commander HARTSFIELD. Well, I guess I've asked myself that question. It's probably not apparent to the people that we meet casually. It may be apparent to the people that we work with every day. But there's no doubt in my mind that when we reached the June 25th date there, that we were keyed up, and we were in excellent mental attitude to fly. I was—I thought the crew was ready; we were all ready to go; and after the pad abort, the next day, there's no doubt that we had a down feeling, as you say. We were a little bit depressed by the whole thing.

We knew that this wasn't going to be a day or two turnaround because we had actually started the engines, and so we were going to have to go inspect the bird, and there was going to be some time involved in getting ready to go again, and the thing that—as the commander, that bothered me a little bit: how do I keep this fine edge on the crew? Fortunately, I think it turned out to take care of itself.

The next couple of weeks after the abort, I think all of us were down, but as the launch time for the second attempt, with the re-manifested flight, came closer, I could detect this rise again in spirit among the crew; we were getting keyed up; we were honing our skills in the simulator; and I think—in fact, I know—the time came to fly the second time, we were ready again and at the same high as we had been before.

Mr. BOEHLERT. Just let me say, Mr. Chairman, you know, sitting here today, I feel like I did when I was a kid and got Ted Williams' autograph.

You know, whenever I'm in the company of people of exceptional ability, like you, and of total commitment and are proven winners, I am thrilled. So I just thank you for that thrill, just not for myself but for all America.

The CHAIRMAN. Thank you, Mr. Boehlert.

Mr. Andrews?

Mr. ANDREWS. Thank you, Mr. Chairman.

I just want to say it's always good to have constituents come to Washington and show their home movies for us.

A serious question—first, just to congratulate you on such a tremendously successful mission—your part, and on the ground, too—so well executed.

I'm curious, physically, about post flight. Were you able to rest enough during the flight to—to—as you moved toward touchdown? Were you exhausted when you finished? Did you feel well rested and still physically alert by the time you finished the flight?

I'm just curious about your—your sleeping and exercise habits on board.

Commander HARTSFIELD. Well, I think for myself, I slept fairly well. I think, observing the crew, that all of us slept less than 8 hours. I would say that the average time devoted to sleep was probably 6 hours, or maybe even a little less. I didn't detect anybody

getting overly tired. I think toward the end of the mission, I'd have to admit, I was tired, and I think some of the crew admitted that they were a little tired.

People's sleeping habits are different; some people don't sleep well, and some sleep extremely well. By the time we got ready to come home though, again, there's a little thing about entry that maybe makes the adrenaline flow a little bit. I think everybody was keyed up, and I could detect at this point no let-down on the part of anybody on the crew. We were all in good shape.

I think we were in good shape when we got on the ground. And, we might have catnapped on the airplane back to Houston, but I think most of us were still going at Houston, because our friends and neighbors were out to greet us late that same evening, which meant that we were approaching 24 hours without sleep and still going strong.

Mr. ANDREWS. Great. It's great to have you back.

Commander HARTSFIELD. Thank you.

Mr. ANDREWS. Thank you, Mr. Chairman.

The CHAIRMAN. Thank you.

Mr. Reid?

Mr. REID. Thank you, Mr. Chairman.

I, too, congratulate you, but I'd like to change the subject a little bit.

Is—what are the reasons we had to have the flight manned? Couldn't most everything have been done without having people on the craft? There's been a lot written about this in the last few months.

Commander HARTSFIELD. Well, I'm not sure of the thrust of your question.

Mr. REID. Do you see—

Commander HARTSFIELD. Regarding the shuttle? The shuttle—

Mr. REID. My question is, do you see the continued need for manned space flight? Could—couldn't a lot of the experiments have been done without people being aboard the craft?

Commander HARTSFIELD. Well, my personal opinion is that, "yes". Man is the only immediately reprogrammable computer that I think we've got that can handle contingency situations and solve problems on the spot. The manned interface has to be there, especially when we look ahead to things like the Space Station to provide the results that we want. The same reason that man has to be present in the laboratory to make things go properly. We cannot turn all of this over to the computer. The computer, in my mind, is an extension of man. It's a faster running device but still does the things he programs it to do.

When we talk about an automatic system, we have to talk about a computer running a system, and there's no way that we can foresee every contingency, in my estimation, to do these things. Some things can be done well by automated craft, and we're doing such things. Some of our outer planetary missions are being done by unmanned craft. Eventually, though, we'll send men out there.

Mr. HAWLEY. If I could just add a couple of points of specific examples as they related to our flight. Hank had mentioned that we were 100 percent successful in doing what we did on the flight and completing the flight plan. The fact of the matter is, we were prob-

ably about 120 percent successful, because we did a lot of things that we knew we were carrying along as payloads of opportunity, if you will. That, because we understood what needed to be done and could in real-time figure out how to fit it into the flight plan, we accomplished.

Second, one of the features that the shuttle has, which is important to emphasize—and we kind of glossed over it a little bit in the movie presentation—is that it's the only opportunity there is right now that we have to checkout those satellites before we commit them to geosynchronous orbit. And, Mike and I spent three days doing that, making sure that all three of those satellites were functional, and proper, and configured the way they were supposed to be. And, I think that when problems develop in the future, as undoubtedly at some point they probably will, that feature will be extremely important to the folks that own those satellites. And, additionally, Mike and Judy can tell you the details, but I watched them successfully replan and execute three days with those tests in flight and managed to accomplish—I don't remember what the numbers were, but it's at least—50 percent more than had been originally programmed in the flight plan—only because they understood what was desired, had interacted with the principal investigators, and knew how to execute it, and managed to execute in the same timeframe at least 50 percent more activities.

Mr. BATEMAN. Mr. Chairman?

If the gentleman would yield, I have some recollection of a problem with the automate—some automated aspect of the electrophoresis experiment. I wonder if Mr. Walker could comment on that, in the context of the human equation in space flight.

Mr. CHARLES WALKER. Yes, sir. In that context, the Electrophoresis Operations in Space payload that I was operating did encounter some problems during the mission, some that we were prepared to implement, such as the replacement of components. One major component did malfunction, and it was necessary to manually replace that in order to continue the operation of the payload. In addition, some unexpected control system problems and situations occurred which required real-time rethinking of our control procedures and, in fact, manual operation of the device through the computer.

I think that the point here is that that is a very good example of a case where private industry, investing their resources in this significant payload, with the objective of, in a few years, developing new commercial operations—industry in space, as such—that with limited resources to be invested, that sending an individual along, as Henry said, the most flexible, reprogrammable computer, and machismo device possible—sending a man along, or a person along, to augment the capabilities of that device, in this case, allowed it to succeed, where mere automation would not. And, I think that is the type of situation that we can look forward to. Industry's involvement will look for these kinds of efficiencies.

Ms. RESNIK. If I might add, I think two of the contingency situations we faced required having people on board.

We did an in-flight maintenance. Mike and I did a swap out of components where if we had not people present, we would not have been able to repair something. That's a very significant part of our

training these days since the first flights. If the capability is there and the tools are there, that with the redundancy in the shuttle systems, that if you have a malfunction in a piece of equipment, you can replace that easily on board.

I think the other demonstration was the task that Henry did with the ice and using the arm. That whole scheme was developed in Houston in simulators by other astronauts and support people working the procedures. They sent up how it was that we were best to get rid of the ice and to survey the situation, and all that was a real-time task that required people executing it, thinking about it, planning it in real-time, and I think that's another demonstration of where the human aspect is very important.

Mr. REID. Thank you, Mr. Chairman.

The CHAIRMAN. I might point out, too, that another was performed in a previous mission where you retrieved a satellite, repaired it, and redeployed it, and that would not have been possible without the presence of—of a person there.

Mr. MacKay?

Mr. MACKAY. Thank you, Mr. Chairman.

I'm—I'm interested in knowing if any of you experienced any motion sickness or other physical problems, and, if so, what—what was the nature of it, and what was your experience of this much time in a weightless environment?

The whole movie, as Mr. Andrews says, gives a very vivid impression of weightlessness. How long did it take to adapt to that, and what physical discomfort did you experience, and has—has—was any of this—if any occurred, was any of this predictable from earlier experience?

Commander HARTSFIELD. I'd like to answer that, if I may.

On our flight, I think our statistics show about what we've seen on previous flights. We have been running, as you know, about 30 to 40 percent of our crews having some symptoms of adaptation, and that occurred also on this flight.

We have thoroughly debriefed our surgeon on this. And, if you'd like, sir, I'd be happy to talk with you in private about it.

Mr. MACKAY. Thank you.

I—I guess the thing that concerns me is, this is the other side of the question about man functioning in space.

Commander HARTSFIELD. Well I understand that. And, I think the important thing to point out here is that in all cases where a person has an adaptation problem, the job gets done.

It's very much like working with a headache or a cold. The symptoms are not the same as—in fact I think I was partly responsible for trying to rename that. We always called it motion sickness, and in a sense I don't think it is. It's an adaptation syndrome because the symptoms are different from individual to individual.

In the cases where nausea is involved, it's not the type of nausea that people on the Earth know, where, like, you're seasick or something where you start feeling bad, and you just get worse, and worse, and worse until maybe eventually you have to empty your stomach.

The nature of this type of illness varies from headache, to knots in the stomach, to malaise, to nausea. Nausea is included in extreme cases, but the nausea is, in general, a sudden nausea. It's not

something that incapacitates you for hours—it's something like, suddenly you're sick, you get rid of it, and you feel good, and you may feel good for another three or four hours.

We're tackling this problem. So far, to answer the first part of your question, we have not found, to my knowledge, any way to predict which individual is going to be attacked by it. We've had people that, for example, have flown all their life. They've never had a bout with any kind of motion sickness on Earth yet have an adaptation problem to zero-G.

I think what's happening there—and we're locking in on this more and more. I'm not, of course, a doctor and can't really speak with a great deal of authority on this, so you have to take my words as just sort of hearsay, talking to my friends who are studying this.

Mr. MACKAY. Well, I suggest, if you've been there, you may be a better authority than a doctor who has not.

Commander HARTSFIELD. But the—I think the evidence is starting to show that the problem is a great deal of confusion in the brain when you get on orbit due to the loss of the one-G vector. And, with that vector missing, the mind now is having to interpret the signals it does get in a new fashion, and I think it takes—the fact that you get over it in a—and generally, the most that anybody's been bothered with it is about 48 hours; some people recover more quickly than that—is that the brain learns a new template.

It is my opinion that if a person flew again in a very short period of time, he probably wouldn't be plagued with it. Now, I can't prove that because we haven't been turning people around that much that have had a problem; they haven't turned that quick; but we're going to get some data on that. It would be nice if we could predict it.

I think the best thing to do is to find something that relieves the symptoms, and I think we're on to something there. I think we've got some data that shows that in some cases the syndrome is caused by the stomach absolutely shutting down. In other words, it doesn't process anything. And we know of drugs that'll turn the stomach on, and we're testing that now with some success.

The important thing—I want to come back to this—the important thing to remember is that in no case to date has a person not been able to do his job even though he's plagued with an adaptation problem. As I said, it's like working with a headache or the sniffles. You don't feel as good, you don't enjoy it while you're working, but you get the job done.

Commander COATS. I'd just like to point out that the very benefits of having man in space—the powers of judgment and observation that you'll never be able to program a computer to do—have never been impaired by this space adaptation syndrome, or whatever you want to call it.

Mr. MACKAY. Thank you, Mr. Chairman.

The CHAIRMAN. Thank you, Mr. MacKay.

Mr. Walker?

Mr. ROBERT WALKER. Thank you, Mr. Chairman.

I'd just like to also join in congratulating the crew and ask Charlie Walker, just for a moment, based upon what you were able to see about the need to manually operate the experiment and the ad-

vantages of having a human presence there, are there recommendations that you now feel that you can take into the commercial community about what kind of machines they should design, what they should expect to do on orbit with robotics, and how much manned presence is going to be needed in order to safely invest in work in space?

Mr. CHARLES WALKER. Well, I think what I returned with is some insight that a well thought out, well conceived, and well planned for experiment or payload operation that is well planned for on the ground can be implemented well in space.

In this case, with the small minimum investment that our company has made in this particular payload, and pressing the capability of the payload, we requested that as a part of that plan and operation and execution, that an individual go along with the equipment on this flight to take up just those contingencies which might require manual operation.

So I think—there aren't that many real unknowns—that to go into space, you do need to have some well conceived and well planned operations.

The industrial community, the payload community, can work very well in some instances with automated equipment—automated artifices, and that's known well ahead of time on the ground. But, at the same time, I think individuals and industries and research organizations that do require hands-on operation, detailed operation, and, in fact, are doing very basic work that requires the mind of man to create instant insights. It's necessary to have that type of capability in operation and available on orbit in space.

So I'm making specific recommendations to our company in that regard—that what we needed to do this time was the right thing to do; but, we're making very strong progress. The data that I've brought back on this flight gives us a very strong input to automated operation where we know that it's going to be capable and the right thing to do.

Mr. ROBERT WALKER. And so you didn't see anything that would cause a major redirection of the plans that were ongoing prior to the flight?

Mr. CHARLES WALKER. No.

Mr. ROBERT WALKER. Thank you, Mr. Chairman.

The CHAIRMAN. Thank you very much, Mr. Walker; and, again, on behalf of the committee, let me congratulate all of the crew and your primary backup crew for a great mission, and we're very proud of everything working well, and after a lot of frustration and getting the flight up, I think it was all worthwhile, and we thank all of you, and congratulate you, and look forward to having you come back again sometime after the next flight.

Commander HARTSFIELD. We'd love to do that, sir, and thank you very much for having us.

The CHAIRMAN. Thank you; and the committee will be adjourned. [Whereupon, at 11:40 a.m., the committee was adjourned.]